A 8912-3U 10/87

SEG

*Special Report*

# *Geophysical Activity in 1986*

*Compiled by the*

***Geophysical Activity Committee***

*Reprinted from GEOPHYSICS: THE LEADING EDGE OF EXPLORATION, Vol. 6, No. 8, August 1987*

# Special Report
# Geophysical Activity in 1986

Gerald E. Montgomery*

Report of the SEG Geophysical Activity Committee. Members of the Committee are Gerald E. Montgomery, Chairman, Data Analyst Russell J. Senti, and Lionel Cane, Charles E. Curtis, Kevin L. Debasitis, John Doherty, Harry R. Espey, Lin Evans, Ronald R. Hartman, Richard Hopkins, Fritz P. Kronberger, Robert C. Lucas, L. G. (Whitey) Morris, James Side, Mike Spradley, Frank Stirling, Paul L. Stoffa, Tommy A. Tillery, A. H. (Tony) Watts, and M. D. (Don) Watts.

## Introduction

Statistical data on worldwide geophysical activity in 1986 is presented in this report. Data were gathered from survey questionnaires that were mailed to 459 oil companies, contractors, government agencies, and institutions throughout the free world. Information has been collected from all users of geophysical techniques in the areas of petroleum, mining, geothermal, and groundwater exploration, and from those who employ geophysical methods in engineering, environmental, oceanography and research. Two hundred fifty-one questionnaires were returned with data for this report; this compares to 214 returns for the 1985 report.

Detailed data were gathered on airborne, drill-hole, land, marine, and transition zone geophysical surveys. Statistics were compiled on miles of coverage, number of stations, drill-hole footage, time spent in crew-months or man-months, and acquisition costs. Data not supplied on the questionnaires by the respondents were estimated on the basis of massive statistical averaging for the area and techniques reported. This process is necessary to avoid distortion of individual statistical items.

This report, when compared to past annual reports, provides a basis for detecting and analyzing trends in technological developments and exploratory trends in geographical areas. Changes in these trends reflect the influence of factors such as oversupply of a particular natural resource, technological advances, and changes in economic conditions, governmental regulations, production controls by a country or countries, and exploration philosophy. Cost figures are also sensitive to many factors such as operational environment, length and nature of the survey, type of instrumentation, etc. Unit costs reported by universities are substantially lower than those reported by industry due to the use of student labor and donated equipment. These costs however, must be averaged with industry costs to accommodate the format of the report. Therefore, when examining unit costs figures, one must be aware of the broad spectrum of activity embraced by individual categories.

Beginning in 1984, the annual questionnaire forms contained revisions to include geophysical methods not reported separately in previous years. The new methods itemized for reporting are vertical seismic profiles (VSPs) and 3-D seismic surveys. Activity information was also requested on surveys performed in transition zones, the areas between normal marine and land survey. Additional survey objectives included on this and last year's forms were environmental and petroleum development. Reported data on these methods and objectives are included in the tables

**Table 1. Total worldwide expenditures in US$ (thousands) by survey type and objective.**

| | Petroleum[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type | Exploration | Development | Minerals | Environmental | Engineering | Geothermal | Groundwater | Oceanography | Research | Total |
| Land | 1,091,362 | 3,413 | 11,107 | 2,079 | 3,447 | 1,104 | 1,586 | | 6,539 | 1,120,637 |
| Transition zone | 20,178 | | | | | | | | | 20,178 |
| Marine | 708,035 | 9,354 | 324 | 615 | 6,830 | | | 3,267 | 4,490 | 732,915 |
| Airborne | 6,985 | | 15,346 | 47 | 54 | 45 | 338 | 304 | 2,610 | 25,728 |
| Drill hole | 796 | 591 | 85 | 15 | 385 | | 331 | | 225 | 2,427 |
| Total | 1,827,356 | 13,358 | 26,863 | 2,755 | 10,716 | 1,149 | 2,255 | 3,570 | 13,863 | 1,901,885 |

[1]Includes processing and interpretation costs for land, transition zone, and marine. See text for details.

*Note:* All tables in this report where figures are expressed in thousands of dollars have been rounded off as individual items; but the computer keeps track of all the truncated numbers and then the sums of the individual items are rounded off. As a result of this procedure, the rounded individual items may not add up precisely to the rounded sums.

*Santa Fe Energy International, 1616 So. Voss, Suite 750, Houston, TX 77057.

Printed in the U.S.A.

for the second time in this 1986 report. This year for the first time it is possible to make a comparison for a change in trends for the new geophysical methods now being reported.

## 1986 highlights

Worldwide expenditures on geophysical exploration in 1986 were down 37 percent from 1985. (See Table 1). This reduction reflects the decrease in total petroleum expenditures of 38 percent; these account for 96.8 percent of the total expenditures on geophysical exploration. Expenditures for engineering (+56%), groundwater (+35%), and mining (+20%) increased from 1985. All other survey objectives showed decreases: oceanography (−61%), research (−49%), environmental (−23%), and geothermal (−10%). For petroleum objectives, there were major decreases in expenditures for land (−37%), transition zone (−60%), and marine (−37%) exploration and development in 1986 compared to 1985. Use of geophysics for petroleum development in 1986 comprised 0.3 percent of total petroleum expenditures for land activity, and 1.3 percent for marine activity. Transition zone seismic was not reported for petroleum development in 1986.

Distribution of expenditures by geographic area and survey objective is shown in Table 2. Only 32 percent of all expenditures for geophysical work was spent in the United States, compared to 44 percent in 1985 and over 50 percent in 1984. There was $1.2 billion less spent on geophysical exploration in the U.S. in 1986 than in 1984. The following areas showed a decrease in total geophysical expenditures compared with 1985: U.S. (−54%), Canada (−56%), Mexico (−23%), South America (−48%), Middle East (−27%), Africa (+1.9%), Europe (−1.1%), and Far East (−9%).

Only one area showed a small increase: Australia/New Zealand (+0.5%). The costs of processing and interpretation are included in Figures 1 and 2 and the petroleum columns of Tables 1 and 2. All other tables show acquisition costs only. Average costs of processing and interpretation were obtained from various processing contractors and oil companies to arrive at a figure of US$565.00 per line-mile for both the Western and Eastern Hemispheres during 1985. It is understood that these costs were lowered significantly in 1986; however, in order to compare acquisition costs between 1985 and 1986, the processing and interpretation costs were kept constant for the two years.

## Petroleum exploration

Nearly 97 percent of all geophysical dollars were spent on petroleum exploration and development (US$1.84 billion) in 1986. Expenditures for petroleum exploration and development declined in the following areas: United States (−55%), Canada (−58%), Mexico (−20%), South America (−47%), Middle East (−27%), Far East (−12%), Europe (−2.3%), and Australia/New Zealand (−1.3%). Only Africa (+.02%) showed a small increase over 1985. Geophysical activity for petroleum exploration and

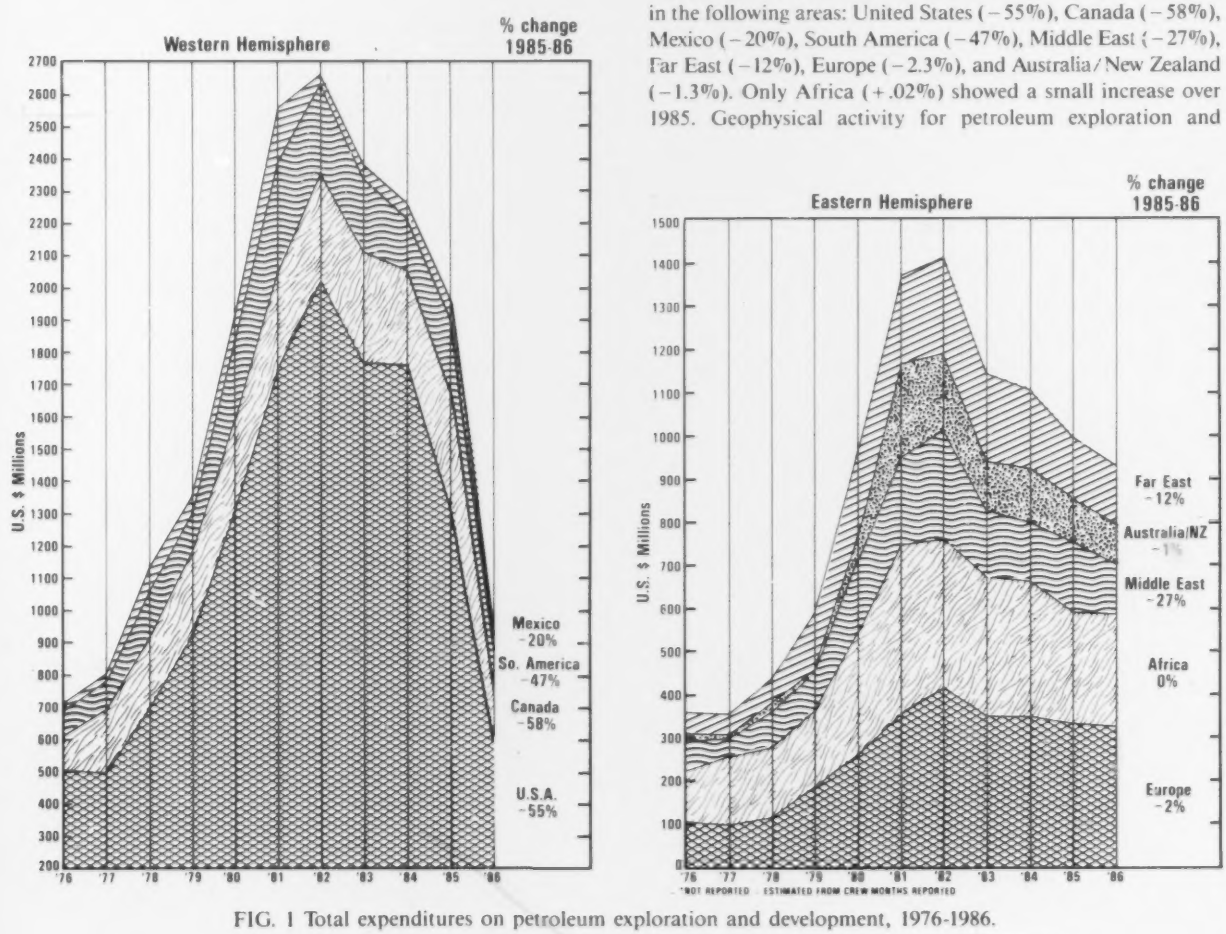


FIG. 1 Total expenditures on petroleum exploration and development, 1976-1986.

**Table 2. Total worldwide expenditures in US$ (thousands) by area and survey objective.**

| Area | Petroleum[1] | | Minerals | Environmental | Engineering | Geothermal | Groundwater | Oceanography | Research | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Exploration | Development | | | | | | | | |
| International | 15,531 | | | 615 | | | | 720 | 1,511 | 18,377 |
| U.S.A. | 581,598 | 8,919 | 1,845 | 1,991 | 6,401 | 135 | 586 | 1,425 | 6,629 | 609,529 |
| Canada | 151,088 | | 10,594 | | 334 | | | | 791 | 162,806 |
| Mexico | 28,080 | | 194 | | | | | | | 28,274 |
| South America | 126,378 | | 20 | | 30 | 111 | | | 2 | 126,541 |
| Europe | 325,678 | 3,389 | 5,528 | 47 | 1,531 | 640 | 24 | 275 | 3,573 | 340,685 |
| Africa | 252,022 | 1,050 | 857 | 19 | 211 | 24 | 1,114 | 250 | 135 | 255,681 |
| Middle East | 117,884 | | | | 230 | | 303 | 900 | | 119,317 |
| Far East | 124,082 | | 3,873 | 1 | 1,084 | 239 | 40 | | | 129,319 |
| Australia/ New Zealand | 105,015 | | 3,951 | 83 | 895 | | 189 | | 1,223 | 111,356 |
| Total | 1,827,356 | 13,358 | 26,863 | 2,755 | 10,716 | 1,149 | 2,255 | 3,570 | 13,863 | 1,901,885 |

[1]Includes processing and interpretation costs for land, transition zone, and marine. See text for details.

development declined 54 percent in the Western Hemisphere and 7 percent in the Eastern Hemisphere. This year for the first time expenditures for petroleum geophysical exploration in the Eastern Hemisphere exceeded costs for exploration in the Western Hemisphere. A 10-year history of geophysical activity in both the Western and Eastern Hemispheres is shown in Figure 1.

## Petroleum seismic surveys

The seismic method accounted for 97 percent of all expenditures in petroleum geophysical activity. This statistic plus the strong tendency for wildcatting to follow and parallel seismic activity, has caused those interested in forecasts of petroleum exploration to regard seismic activity as a barometer for exploration. A 10-year history of the cost of petroleum seismic surveys in both Eastern and Western Hemispheres is shown in Figure 2. In the Western Hemisphere, acquisition costs per mile of land seismic surveys increased 4 percent, while marine costs decreased 17 percent. In the Eastern Hemisphere, acquisition cost per mile for land seismic decreased 3 percent, while marine costs were reduced by only 2 percent. The total number of miles of seismic data recorded worldwide was down 39 percent for land and 32 percent for marine work, as shown in Tables 3 and 5 which do not include

*(Text continued on p. 36)*

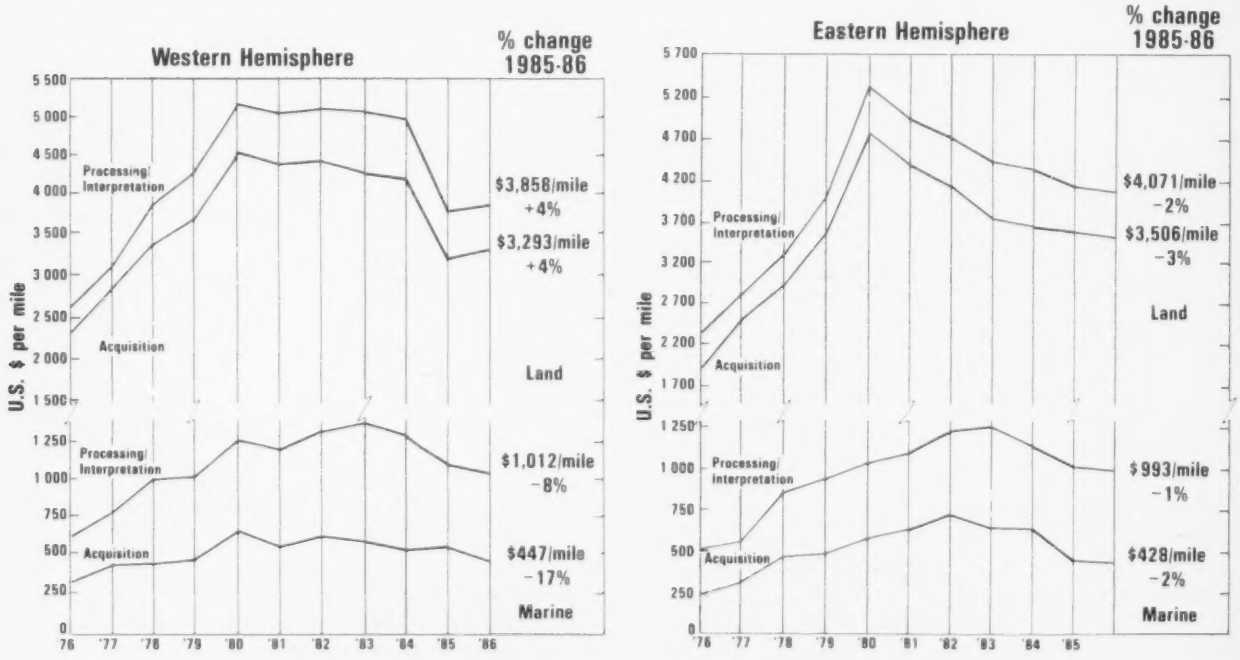


FIG. 2 Average cost per mile for petroleum seismic surveys, 1976-1986.

**Table 3. Worldwide petroleum land seismic activity.**

| Area | Acquisition costs - US$ | Line-miles | Crew-months Company* | Crew-months Contract | Crew-months total* | Average miles/month | Average cost/month | Average cost/mile |
|---|---|---|---|---|---|---|---|---|
| U.S.A. | 291,139,815 | 67,561 | 338.2 | 1,427.5 | 1,765.7 | 38 | 164,886 | 4,309 |
| | [280,000] | [17] | | [2.0] | [2.0] | [9] | [140,000] | [16,471] |
| Canada | 107,167,669 | 46,060 | 59.5 | 382.6 | 442.1 | 104 | 242,406 | 2,327 |
| | [3,760,000] | [177] | | [9.2] | [9.2] | [19] | [408,696] | [21,243] |
| Mexico | 11,749,000 | 10,510 | | 261.0 | 261.0 | 40 | 45,015 | 1,117 |
| South America | 92,699,912 | 28,545 | | 370.5 | 370.5 | 77 | 250,202 | 3,247 |
| Europe | 84,042,986 | 20,356 | | 429.3 | 429.3 | 47 | 195,767 | 4,128 |
| Africa | 116,702,232 | 32,937 | | 436.9 | 436.9 | 75 | 267,114 | 3,543 |
| Middle East | 91,059,035 | 25,651 | | 282.0 | 282.0 | 91 | 322,904 | 3,550 |
| Far East | 67,797,082 | 18,726 | | 374.3 | 374.3 | 50 | 181,130 | 3,620 |
| Australia/ New Zealand | 52,336,264 | 19,833 | | 200.5 | 200.5 | 98 | 261,028 | 2,638 |
| Total | 914,693,995 | 270,179 | 397.7 | 4,164.6 | 4,562.3 | 59 | 200,490 | 3,386 |
| | [4,040,000] | [194] | | [11.2] | [11.2] | [17] | [360,714] | [20,825] |

[1] All data enclosed in [brackets] pertain to 3-D surveys reported in square miles.

*Total includes government and university activity, if any.

**Table 4. Worldwide petroleum land seismic line-miles by energy source and 3-D survey.**

| Area | Dynamite | Compressed air | Gas exploder | Weight drop | Solid chemical | Vibrator | 3-D surveys Line-miles | 3-D surveys Square miles | Other | Total line-miles |
|---|---|---|---|---|---|---|---|---|---|---|
| U.S.A. | 23,136 | 2,895 | | 193 | 9 | 40,850 | 464 | 17 | 13 | 67,561 |
| Canada | 26,480 | 1,513 | | 778 | | 9,669 | 7,620 | 177 | | 46,060 |
| Mexico | 5,640 | | | | | 4,870 | | | | 10,510 |
| South America | 18,509 | | | | | 10,036 | | | | 28,545 |
| Europe | 7,740 | | | 39 | | 12,577 | | | | 20,356 |
| Africa | 10,079 | 675 | 1,832 | 495 | | 19,856 | | | | 32,937 |
| Middle East | 5,082 | | 31 | 2,255 | | 15,959 | 2,322 | | | 25,651 |
| Far East | 14,426 | 205 | | 448 | | 3,647 | | | | 18,726 |
| Australia/ New Zealand | 2,512 | 700 | | | | 16,620 | | | | 19,833 |
| Total | 113,605 | 5,988 | 1,864 | 4,208 | 9 | 134,088 | 10,406 | 194 | 13 | 270,179 |

**Table 5. Worldwide petroleum marine seismic activity.**

| Area | Acquisition costs - US$ | Line-miles | Crew-months Company* | Crew-months Contract | Crew-months total* | Average miles/month | Average cost/month | Average cost/mile |
|---|---|---|---|---|---|---|---|---|
| International | 15,531,426 | 15,270 | | 24.8 | 24.8 | 615 | 626,267 | 1,017 |
| U.S.A. | 110,018,366 | 252,227 | 63.0 | 187.4 | 250.4 | 1,007 | 439,370 | 436 |
| Canada | 7,451,000 | 9,010 | | 11.0 | 11.0 | 819 | 677,363 | 826 |
| Mexico | 3,078,000 | 9,472 | | 15.0 | 15.0 | 631 | 205,200 | 324 |
| South America | 7,775,200 | 16,465 | | 29.6 | 29.6 | 556 | 262,675 | 472 |
| Europe | 99,770,029 | 224,754 | | 273.7 | 273.7 | 821 | 364,523 | 444 |
| Africa | 44,177,438 | 118,442 | | 120.8 | 120.8 | 980 | 365,707 | 373 |
| Middle East | 4,351,144 | 13,292 | | 13.4 | 13.4 | 992 | 324,712 | 327 |
| Far East | 12,939,400 | 24,219 | | 29.1 | 29.1 | 832 | 444,652 | 534 |
| Australia/ New Zealand | 17,223,000 | 36,302 | | 32.0 | 32.0 | 1,134 | 538,218 | 474 |
| Total | 322,315,003 | 719,453 | 63.0 | 736.8 | 799.8 | 899 | 402,995 | 448 |

*Total includes government and university activity, if any.

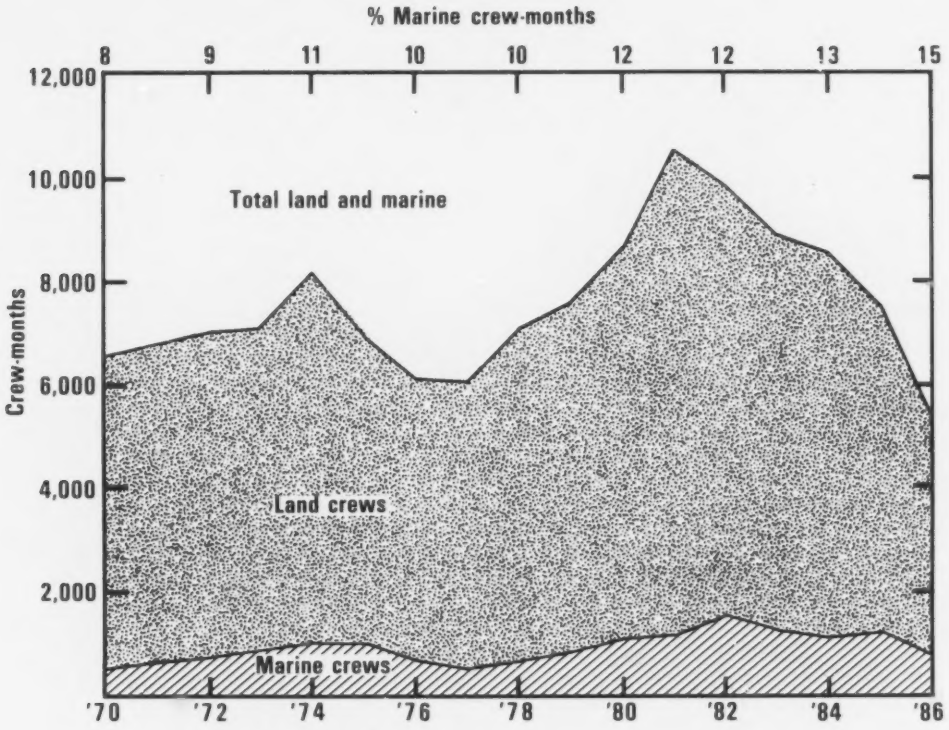


FIG. 3 Worldwide seismic activity in crew-months, 1970-1986.

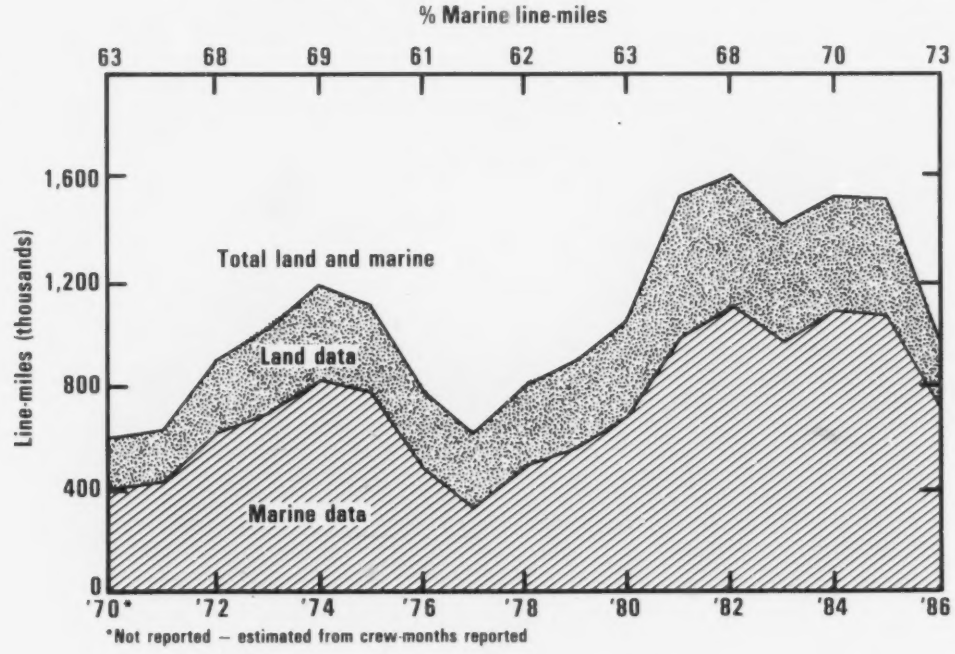


FIG. 4 Worldwide seismic activity in line-miles, 1970-1986.

**Table 6. Worldwide petroleum marine seismic line-miles by energy source and 3-D survey.**

| Area | Compressed Air | Implosive | 3-D surveys | | Total Line-miles |
|---|---|---|---|---|---|
| | | | Line-miles | Square-miles | |
| International | 15,270 | | | | 15,270 |
| U.S.A. | 216,174 | | 36,053 | | 252,227 |
| Canada | 9,010 | | | | 9,010 |
| Mexico | 9,472 | | | | 9,472 |
| South America | 16,465 | | | | 16,465 |
| Europe | 190,295 | 1,493 | 32,965 | | 224,753 |
| Africa | 108,120 | 7,462 | 2,860 | | 118,442 |
| Middle East | 12,409 | 883 | | | 13,292 |
| Far East | 24,219 | | | | 24,219 |
| Australia/ New Zealand | 36,302 | | | | 36,302 |
| Total | 637,737 | 9,839 | 71,878 | 0 | 719,453 |

**Table 7. Worldwide average unit costs for petroleum surveys.**

| Area, survey type, and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs - US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew-month or man-month* | Average cost/ mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **International** | | | | | | |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 24.8 | 15,270 | 15,531,426 | 616 | 626,267 | 1,017 |
| **U.S.A.** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 719.8 | 23,131 | 120,594,785 | 32 | 167,523 | 5,213 |
| Compressed air | 51.3 | 2,895 | 9,678,496 | 56 | 188,665 | 3,343 |
| Weight drop | 4.0 | 193 | 550,000 | 48 | 137,500 | 2,850 |
| Solid chemical | .3 | 9 | 36,051 | 27 | 109,245 | 4,006 |
| Vibratory | 980.9 | 40,850 | 157,881,863 | 42 | 160,943 | 3,865 |
| Other | .5 | 13 | 88,000 | 26 | 176,000 | 6,769 |
| Seismic (*S*-wave) | | | | | | |
| Dynamite | .5 | 5 | 120,000 | 10 | 240,000 | 24,000 |
| 3-D seismic | | | | | | |
| Line-miles | 8.3 | 464 | 2,190,620 | 56 | 263,930 | 4,721 |
| Square miles | 2.0 | 17 | 280,000 | 9 | 140,000 | 16,000 |
| VSPs | 3.0 | [13] | 902,540 | [4] | 300,847 | [69,426] |
| Gravity | 14.0 | 2,188 | 196,660 | 156 | 14,047 | 90 |
| Gravity | 7.3 | [5,102] | 309,500 | [699] | 42,397 | [61] |
| Magnetic | 1.0* | [300] | 10,000 | [300]* | 10,000* | [33] |
| Magnetotelluric | | | | | | |
| Natural field | 1.0 | 150 | 75,000 | 150 | 75,000 | 500 |
| Natural field | .2 | [2] | 5,000 | [10] | 25,000 | [2,500] |
| Other | 3.2 | 56 | 325,000 | 18 | 101,563 | 5,804 |
| Transition zone | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 8.1 | 369 | 2,027,786 | 46 | 250,344 | 5,495 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 220.4 | 216,174 | 97,249,366 | 981 | 441,240 | 450 |
| 3-D seismic | | | | | | |
| Line-miles | 30.0 | 36,053 | 12,769,000 | 1,202 | 425,633 | 354 |
| VSPs | .2 | [1] | 100,000 | [5] | 500,000 | [100,000] |

**Table 7. Worldwide average unit costs for petroleum surveys (cont.).**

| Area, survey type, and method | Total crew months or man-months* | Miles or (footage) or [stations] | Acquisition costs - US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **U.S.A.**, Marine, continued | | | | | | |
| Gravity | 1.0 | 620 | 20,000 | 620 | 20,000 | 32 |
| Gravity | 28.0* | 17,530 | 830,000 | 626* | 29,643* | 47 |
| Gravity | 2.0* | [517] | 220,000 | [259]* | 110,000* | [426] |
| Other | .2 | 60 | 20,000 | 240 | 80,000 | 333 |
| Airborne | | | | | | |
| Magnetic | 25.6 | 171,525 | 3,128,000 | 6,687 | 121,949 | 18 |
| Magnetic | .1* | 600 | 7,200 | 20,000* | 240,000* | 12 |
| Remote sensing | | | | | | |
| Multispectral scanning | .5 | 248 | 7,936 | 496 | 15,872 | 32 |
| Drill hole | | | | | | |
| Other | .3* | [970] | 194,000 | [2,771]* | 554,286* | [200] |
| **Canada** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 274.8 | 26,480 | 76,404,256 | 96 | 278,036 | 2,885 |
| Compressed air | 11.0 | 1,513 | 2,194,000 | 138 | 199,455 | 1,450 |
| Weight drop | 6.2 | 778 | 1,357,000 | 125 | 218,871 | 1,744 |
| Vibratory | 145.4 | 9,669 | 25,120,746 | 67 | 172,770 | 2,598 |
| 3-D seismic | | | | | | |
| Line-miles | 4.7 | 7,620 | 2,091,667 | 1,621 | 445,036 | 274 |
| Square miles | 9.2 | 177 | 3,760,000 | 19 | 408,696 | 21,207 |
| VSPs | .4 | [4] | 40,000 | [10] | 100,000 | [10,000] |
| Other | 2.0 | 21 | 90,000 | 11 | 45,000 | 4,286 |
| Transition zone | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 1.5 | 60 | 830,000 | 40 | 553,333 | 13,833 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 11.0 | 9,010 | 7,451,000 | 819 | 677,364 | 827 |
| Airborne | | | | | | |
| Magnetic | 3.2 | 23,000 | 385,000 | 7,188 | 120,313 | 17 |
| Combined EM/Mag. | | | | | | |
| VLF | .1 | 85 | 4,000 | 1,700 | 80,000 | 47 |
| Drill hole | | | | | | |
| Other | .1* | [60] | 43,000 | [2,000]* | 1,433,333* | [717] |
| Other | .1* | (9,000) | 44,000 | (90,000)* | 440,000* | (5) |
| **Mexico** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 150.0 | 5,640 | 6,089,000 | 38 | 40,593 | 1,080 |
| Vibratory | 111.0 | 4,870 | 5,660,000 | 44 | 50,991 | 1,162 |
| Gravity | 195.0 | 7,780 | 916,000 | 40 | 4,697 | 118 |
| Magnetotelluric | | | | | | |
| Natural field | 17.0 | [242] | 266,000 | [14] | 15,647 | [1,099] |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 15.0 | 9,472 | 3,078,000 | 631 | 205,200 | 325 |
| Airborne | | | | | | |
| Magnetic | 2.0 | 25,800 | 516,000 | 12,900 | 258,000 | 20 |
| Drill hole | | | | | | |
| Sonic/velocity logging | 12.0 | (72,000) | 265,000 | (6,000) | 22,083 | (4) |

**Table 7. Worldwide average unit costs for petroleum surveys (cont.).**

| Area, survey type, and method | Total crew months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **South America** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 224.8 | 18,509 | 64,885,162 | 82 | 288,635 | 3,506 |
| Vibratory | 145.7 | 10,036 | 27,814,750 | 69 | 190,904 | 2,771 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 29.6 | 16,465 | 7,775,200 | 556 | 262,676 | 472 |
| Airborne | | | | | | |
| Gravity | 1.0 | 19,000 | 428,000 | 19,000 | 428,000 | 23 |
| Magnetic | .2 | 1,100 | 43,500 | 4,400 | 174,000 | 40 |
| **Europe** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 224.2 | 7,740 | 35,915,872 | 35 | 160,196 | 4,640 |
| Weight drop | 1.2 | 39 | 240,000 | 33 | 200,000 | 6,154 |
| Vibratory | 203.9 | 12,577 | 47,887,114 | 62 | 234,856 | 3,807 |
| VSPs | 38.6 | [133] | 1,365,700 | [3] | 35,381 | [13,007] |
| Gravity | 14.0 | [11,616] | 425,952 | [830] | 30,425 | [37] |
| Resistivity | 17.0 | 816 | 204,000 | 48 | 12,000 | 250 |
| Electromagnetic | | | | | | |
| Time domain | .5 | [55] | 82,000 | [110] | 164,000 | [1,491] |
| Transition zone | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 5.0 | 50 | 1,800,000 | 10 | 360,000 | 36,000 |
| Compressed air | 13.1 | 917 | 550,200 | 70 | 42,000 | 600 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 231.6 | 198,295 | 84,393,060 | 804 | 356,691 | 443 |
| Implosive | 2.3 | 1,493 | 537,669 | 628 | 225,911 | 360 |
| 3-D seismic | | | | | | |
| Line-miles | 34.8 | 32,965 | 14,839,300 | 946 | 425,683 | 450 |
| Gravity | 20.0* | 11,900 | 351,000 | 595* | 17,550* | 29 |
| Other | 2.3 | 1,740 | 783,000 | 750 | 337,500 | 450 |
| Airborne | | | | | | |
| Magnetic | 11.5 | 39,813 | 936,712 | 3,462 | 81,453 | 24 |
| Radiometric | | | | | | |
| Gamma ray | 1.6 | 10,094 | 252,350 | 6,044 | 151,108 | 25 |
| Drill hole | | | | | | |
| Sonic/velocity logging | 5.8 | [20,392] | 16,314 | [3,516] | 2,813 | [1] |
| **Africa** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 150.0 | 10,079 | 30,530,385 | 67 | 203,536 | 3,029 |
| Compressed air | 5.0 | 675 | 876,000 | 135 | 175,200 | 1,298 |
| Gas exploder | 38.2 | 1,832 | 9,415,160 | 48 | 246,470 | 5,138 |
| Weight drop | 8.0 | 495 | 2,190,000 | 62 | 273,750 | 4,424 |
| Vibratory | 235.7 | 19,856 | 73,690,687 | 84 | 312,646 | 3,711 |
| Gravity | 25.3 | 2,875 | 334,000 | 114 | 13,202 | 116 |
| Gravity | 16.0 | [12,118] | 529,958 | [757] | 33,122 | [44] |
| Gravity | 12.0* | [10,100] | 950,000 | [842]* | 79,167* | [94] |
| Magnetic | 4.0 | 110 | 4,600 | 28 | 1,150 | 42 |
| Magnetic | 3.5 | [7,134] | 335,298 | [2,038] | 95,799 | [47] |

**Table 7. Worldwide average unit costs for petroleum surveys (cont.).**

| Area, survey type, and method | Total crew months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Africa,** Land, continued | | | | | | |
| Electromagnetic | | | | | | |
| Frequency domain | 2.0 | 9 | 5,000 | 5 | 2,500 | 556 |
| Induced polarization | | | | | | |
| Time domain | 3.0 | 7 | 26,000 | 2 | 8,667 | 3,714 |
| Magnetotelluric | | | | | | |
| Natural field | 1.5 | [11] | 19,404 | [7] | 12,936 | [1,764] |
| Transition zone | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | .6 | 16 | 9,200 | 27 | 15,333 | 575 |
| Gas exploder | 6.3 | 253 | 3,109,283 | 40 | 493,537 | 12,261 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 107.9 | 108,120 | 40,224,115 | 1,002 | 372,687 | 372 |
| Implosive | 11.8 | 7,462 | 2,666,323 | 630 | 225,196 | 357 |
| 3-D seismic | | | | | | |
| Line-miles | 1.1 | 2,860 | 1,287,000 | 2,600 | 1,170,000 | 450 |
| Gravity | 6.0 | 3,720 | 120,000 | 620 | 20,000 | 32 |
| Gravity | 12.0* | 10,550 | 211,000 | 879* | 17,583* | 20 |
| Airborne | | | | | | |
| Magnetic | 3.2 | 14,463 | 480,500 | 4,450 | 147,846 | 33 |
| Radiometric | | | | | | |
| Gamma ray | 4.1 | 21,163 | 529,075 | 5,087 | 127,181 | 25 |
| **Middle East** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 85.0 | 5,082 | 19,999,733 | 60 | 235,291 | 3,935 |
| Gas exploder | .4 | 31 | 82,629 | 79 | 206,573 | 2,607 |
| Weight drop | 33.0 | 2,255 | 14,105,175 | 68 | 427,430 | 6,253 |
| Vibratory | 162.1 | 15,959 | 56,046,773 | 98 | 345,754 | 3,512 |
| 3-D seismic | | | | | | |
| Line-miles | 1.5 | 2,322 | 824,725 | 1,548 | 549,817 | 355 |
| VSPs | 2.3 | [8] | 60,288 | [3] | 26,212 | [7,536] |
| Gravity | 3.0 | [2,424] | 114,868 | [808] | 38,289 | [47] |
| Gravity | 2.0* | [600] | 69,000 | [300]* | 34,500* | [115] |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 12.0 | 12,409 | 4,033,000 | 1,034 | 336,083 | 325 |
| Implosive | 1.4 | 883 | 318,144 | 631 | 227,246 | 360 |
| Gravity | 4.0* | 7,800 | 175,000 | 1,950* | 43,750* | 22 |
| Airborne | | | | | | |
| Magnetic | 5.0 | 2,600 | 52,000 | 520 | 10,400 | 20 |
| **Far East** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 301.4 | 14,426 | 50,814,602 | 48 | 168,595 | 3,522 |
| Compressed air | 4.0 | 205 | 840,000 | 51 | 210,000 | 4,098 |
| Weight drop | 5.9 | 448 | 1,335,040 | 76 | 226,278 | 2,980 |
| Vibratory | 63.0 | 3,647 | 14,807,440 | 58 | 235,039 | 4,060 |
| Other | 18.6 | 911 | 6,732,340 | 49 | 361,954 | 7,390 |
| Transition zone | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 4.7 | 705 | 422,400 | 150 | 89,872 | 599 |

**Table 7. Worldwide average unit costs for petroleum surveys (cont.).**

| Area, survey type, and method | Total crew months or man-months* | Miles or (footage) or [stations] | Acquisition costs - US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Far East**, continued | | | | | | |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 29.1 | 24,219 | 12,939,400 | 832 | 444,653 | 534 |
| Gravity | 2.0 | 1,730 | 42,000 | 865 | 21,000 | 24 |
| Gravity | 15.0* | 10,760 | 380,000 | 717* | 25,333* | 35 |
| Other | 4.4 | 24,800 | 11,160,000 | 5,636 | 2,536,364 | 450 |
| Airborne | | | | | | |
| Gravity | 1.5 | 2,500 | 164,000 | 1,667 | 109,333 | 66 |
| Remote sensing | | | | | | |
| Multispectral scanning | .7 | 2,128 | 51,072 | 2,837 | 68,096 | 24 |
| Drill hole | | | | | | |
| Other | .3* | (11,800) | 130,000 | (39,333)* | 433,333* | (11) |
| **Australia/New Zealand** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 39.6 | 2,504 | 8,686,713 | 63 | 219,361 | 3,468 |
| Compressed air | 7.0 | 700 | 3,300,000 | 100 | 471,429 | 4,714 |
| Vibratory | 150.9 | 16,620 | 40,303,551 | 110 | 267,088 | 2,425 |
| Seismic (*S*-wave) | | | | | | |
| Dynamite | 1.0 | 5 | 13,000 | 6 | 13,000 | 2,364 |
| Seismic (refraction) | | | | | | |
| Dynamite | .5 | 2 | 10,000 | 5 | 20,000 | 4,000 |
| VSPs | 4.1 | [13] | 97,968 | [3] | 23,895 | [7,536] |
| Gravity | 11.0 | [15,800] | 149,000 | [1,436] | 13,545 | [9] |
| Other | 48.0 | [96] | 2,153,000 | [2] | 44,854 | [22,427] |
| Transition zone | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Solid chemical | 2.2 | 142 | 1,100,000 | 63 | 488,889 | 7,714 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 32.0 | 36,302 | 17,223,000 | 1,134 | 538,219 | 474 |
| Drill hole | | | | | | |
| Sonic/velocity logging | 1.0 | (6,000) | 25,000 | (6,000) | 25,000 | (4) |
| Magnetotelluric | | | | | | |
| Natural field | 4.0 | (130,000) | 70,000 | (32,500) | 17,500 | (1) |
| Remote sensing | | | | | | |
| Thermal infrared | 6.0 | (120,000) | 120,000 | (20,000) | 20,000 | (1) |
| Other | 1.5 | (36,000) | 23,000 | (24,000) | 15,333 | (1) |

**Table 8. U.S.A. petroleum seismic activity by area.**

| Survey type, state | Acquisition costs – US$ | Line-miles | Crew-months | | Crew-months total* |
|---|---|---|---|---|---|
| | | | Company* | Contract | |
| **Land** | | | | | |
| Alaska | 8,370,771 | 1,849 | .0 | 16.0 | 16.0 |
| Alabama | 3,624,689 | 677 | 3.9 | 12.0 | 15.9 |
| Arkansas | 1,839,485 | 449 | 3.3 | 8.5 | 11.8 |
| Arizona | 379,000 | 142 | .0 | 5.0 | 5.0 |
| California | 19,334,044 | 4,848 | 15.0 | 109.6 | 124.7 |
| | [100,000] | [10] | | [1.0] | [1.0] |
| Colorado | 16,053,537 | 3,466 | 20.3 | 63.5 | 83.8 |
| Connecticut | 393,600 | 3 | 1.0 | .0 | 1.0 |
| Delaware | 61,768 | 57 | .0 | 1.0 | 1.0 |
| Florida | 3,549,644 | 194 | 6.1 | .0 | 6.1 |
| Idaho | 734,000 | 43 | 2.0 | 1.0 | 3.0 |
| Illinois | 64,729 | 30 | .0 | .6 | .6 |
| Kansas | 4,056,938 | 1,623 | 1.0 | 34.0 | 35.0 |
| Kentucky | 125,000 | 31 | .0 | 1.2 | 1.2 |
| Louisiana | 26,991,496 | 4,687 | 36.8 | 120.6 | 157.4 |
| Maryland | 425,700 | 27 | 1.0 | .3 | 1.3 |
| Michigan | 39,491,988 | 9,106 | 55.5 | 203.7 | 259.2 |
| Missouri | 37,697 | 16 | .0 | .4 | .4 |
| Mississippi | 8,378,178 | 1,319 | 17.4 | 20.5 | 37.9 |
| | [50,000] | [4.5] | | [.5] | [.5] |
| Montana | 7,402,101 | 1,711 | 14.8 | 31.7 | 46.5 |
| North Carolina | 720 | 16 | .0 | .4 | .4 |
| North Dakota | 5,374,966 | 1,861 | 2.0 | 40.0 | 42.0 |
| Nebraska | 1,273,042 | 400 | .0 | 7.2 | 7.2 |
| New Mexico | 12,221,013 | 2,932 | 12.2 | 58.5 | 70.7 |
| Nevada | 3,518,093 | 441 | 1.0 | 14.7 | 15.7 |
| New York | 438,763 | 315 | .0 | 6.5 | 6.5 |
| Ohio | 166,000 | 47 | .0 | 2.0 | 2.0 |
| Oklahoma | 16,452,030 | 4,477 | 14.5 | 115.5 | 130.0 |
| Oregon | 2,057,000 | 350 | .0 | 8.0 | 8.0 |
| Pennsylvania | 1,456,000 | 558 | .0 | 13.1 | 13.1 |
| South Carolina | 1,191,000 | 467 | .0 | 12.0 | 12.0 |
| South Dakota | 386,000 | 177 | .0 | 6.5 | 6.5 |
| Texas | 76,070,688 | 18,915 | 94.1 | 386.8 | 481.0 |
| Utah | 1,559,985 | 226 | .5 | 9.5 | 10.0 |
| Virginia | 655,308 | 259 | .0 | 7.4 | 7.4 |
| Washington | 7,304,140 | 1,203 | 14.5 | 14.3 | 28.8 |
| West Virginia | 161,834 | 44 | .0 | 1.6 | 1.6 |
| Wyoming | 19,538,868 | 4,588 | 20.7 | 93.6 | 114.4 |
| | [130,000] | [3] | | [.5] | [.5] |
| Total land | 291,139,815 | 67,561 | 338.2 | 1,427.5 | 1,765.7 |
| | [280,000] | [17.5] | | [2.0] | [2.0] |
| **Transition Zone** | | | | | |
| Gulf Coast | 2,027,786 | 369 | 2.1 | 6.0 | 8.1 |
| **Marine** | | | | | |
| Off Alaska | 1,300,000 | 1,226 | .0 | 2.2 | 2.2 |
| East Coast | 283,000 | 800 | .0 | 2.0 | 2.0 |
| Gulf Coast | 82,520,366 | 189,049 | 63.0 | 144.3 | 207.3 |
| West Coast | 25,915,000 | 61,152 | 0 | 38.9 | 38.9 |
| Total marine | 110,018,366 | 252,227 | 63.0 | 187.4 | 250.4 |
| Total U.S.A. | 403,185,967 | 320,157 | 403.3 | 1,620.9 | 2,024.2 |
| | [280,000] | [17.5] | | [2.0] | [2.0] |

*Total includes government and university activity, if any.

All data enclosed in [brackets] pertain to 3-D surveys reported in square miles.

**Table 9. Canada petroleum Seismic activity by area.**

| Survey type, province | Acquisition costs - US$ | Line-miles | Crew-months | | Crew-months total* |
|---|---|---|---|---|---|
| | | | Company* | Contract | |
| **Land** | | | | | |
| Undesignated | 11,326,240 | 3,120 | .0 | 63.0 | 63.0 |
| Alberta | 85,990,560 | 40,017 | 55.5 | 285.8 | 341.3 |
| | [3,730,000] | [171.8] | | [8.9] | [8.9] |
| British Columbia | 2,423,360 | 532 | 1.0 | 8.3 | 9.3 |
| | [20,000] | [4.0] | | [.2] | [.2] |
| Manitoba | 283,000 | 90 | .0 | 1.0 | 1.0 |
| Northwest Territories | 3,320,000 | 712 | .0 | 12.5 | 12.5 |
| Saskatchewan | 3,824,509 | 1,587 | 3.0 | 11.9 | 14.9 |
| | [10,000] | [1.5] | | [.1] | [.1] |
| Total land | 107,167,669 | 46,060 | 59.5 | 382.6 | 442.1 |
| | [3,760,000] | [177.3] | | [9.2] | [9.2] |
| **Transition Zone** | | | | | |
| Alberta | 830,000 | 60 | .0 | 1.5 | 1.5 |
| **Marine** | | | | | |
| Undesignated | 6,700,000 | 6,700 | .0 | 8.0 | 8.0 |
| Alberta | 751,000 | 2,310 | .0 | 3.0 | 3.0 |
| Total Marine | 7,451,000 | 9,010 | .0 | 11.0 | 11.0 |
| Total Canada | 115,448,669 | 55,130 | 59.5 | 395.1 | 454.6 |
| | [3,760,000] | [177.3] | | [9.2] | [9.2] |

*Total includes government and university activity, if any.

All data enclosed in [brackets] pertain to 3-D surveys reported in square miles.

*(Continued from p. 27)*

activity reported for the transition zone. There was a sharp decrease of over 500,000 miles of seismic worldwide, while the cost per mile showed a slight increase in land cost and a decrease in the cost of a marine seismic survey.

Vibroseis was again this year the most popular land seismic energy source with dynamite the second most used source. These two energy sources accounted for 92 percent of all seismic land work. Air gun (compressed air) as a source, which accounted for 12 percent of land work in 1985, only totaled 2 percent of all land work in 1986 (Table 4). In marine work only compressed air and implosive sources were reported as being used, with air guns accounting for 98 percent of total line-miles recorded (Table 6).

One can refer to Table 7 for a more comprehensive breakdown of statistical data on petroleum surveys, which are sorted by geographic area. Table 8 shows petroleum seismic activity by states in the U.S. Against a 1986 decline rate of 48 percent for overall onshore geophysical expenditures in the U.S., Michigan, New Mexico, Nebraska, and Washington either experienced only very slight declines or had actual increases in geophysical expenditures. This is shown in greater detail on Table 8.

In 1985, 15 states had expenditures greater than $10 million. Only 8 states passed that mark in 1986. Texas accounted for over one-quarter of all U.S. onshore expenditures on seismic exploration in 1986. Michigan, the number two state for the first time, had 15 percent of the total. Louisiana and Wyoming accounted for 10 percent and 7 percent, respectively. California, Oklahoma, and Colorado each had about 6 percent of all expenditures; and New Mexico, the newcomer to the top 8 in 1986, accounted for 4 percent. The states with the largest decreases in 1986 were Alaska, Arkansas, Illinois, Kentucky, Missouri, Ohio, Utah, and West Virginia. No activity was reported from the following states that were active in 1985: Georgia, Indiana, Iowa, Minnesota, and Tennessee. Because seismic exploration activity usually

*(Text continued on p. 49)*

**Table 10. Petroleum seismic activity in Mexico.**

| Survey type | Acquisition costs - US$ | Line-miles | Crew-months | | Total months |
|---|---|---|---|---|---|
| | | | Company | Contract | |
| **Land** | | | | | |
| Various | 11,749,000 | 10,510 | .0 | 261.0 | 261.0 |
| **Marine** | | | | | |
| Various | 3,078,000 | 9,472 | .0 | 15.0 | 15.0 |
| Total Mexico | 14,827,000 | 19,982 | .0 | 276.0 | 276.0 |

**Table 11. Total worldwide expenditures on gravity and magnetic surveys in US$ (thousands).**

| Area | Petroleum exploration | Minerals | Environmental | Engineering | Geothermal | Groundwater | Oceanography | Research | Total |
|---|---|---|---|---|---|---|---|---|---|
| International | | | | | | | | 1,298 | 1,298 |
| U.S.A. | 4,721 | 199 | 91 | 62 | | 12 | 303 | 772 | 6,162 |
| Canada | 385 | 1,646 | | 3 | | | | | 2,034 |
| Mexico | 1,432 | 83 | | | | | | | 1,515 |
| South America | 471 | | | | 100 | | | 1 | 573 |
| Europe | 1,713 | 3 | | 189 | | | | 120 | 2,026 |
| Africa | 2,965 | 256 | 3 | | | 456 | | 78 | 3,759 |
| Middle East | 410 | | | | | 302 | | | 713 |
| Far East | 586 | 3,821 | 1 | 20 | 63 | | | | 4,491 |
| Australia/ New Zealand | 149 | 1,550 | 12 | | | 4 | | 994 | 2,710 |
| Total | 12,834 | 7,560 | 108 | 274 | 163 | 776 | 303 | 3,264 | 25,286 |

**Table 12. Total worldwide expenditures on airborne surveys in US$ (thousands).**

| Area | Petroleum exploration | Minerals | Environmental | Engineering | Geothermal | Groundwater | Oceanography | Research | Total |
|---|---|---|---|---|---|---|---|---|---|
| U.S.A. | 3,143 | 288 | | 54 | | 35 | 303 | 1,082 | 4,906 |
| Canada | 389 | 8,449 | | | | | | 443 | 9,281 |
| Mexico | 516 | 50 | | | | | | | 566 |
| South America | 471 | | | | | | | | 471 |
| Europe | 1,189 | 790 | 46 | | | | | 284 | 2,310 |
| Africa | 1,009 | 25 | | | | | | | 1,034 |
| Middle East | 52 | | | | | 302 | | | 354 |
| Far East | 215 | 3,800 | | | 45 | | | | 4,060 |
| Australia/ New Zealand | | 1,942 | | | | | | 800 | 2,742 |
| Total | 6,985 | 15,346 | 46 | 54 | 45 | 337 | 303 | 2,609 | 25,728 |

**Table 13A. Western Hemisphere airborne activity in US$ (thousands).**

| | USA | | Canada | | Mexico | | South America | |
|---|---|---|---|---|---|---|---|---|
| Survey method | Line-miles | Cost | Line-miles | Cost | Line-miles | Cost | Line-miles | Cost |
| Gravity | 2,400 | 325 | | | | | 19,000 | 428 |
| Magnetic | 218,056 | 3,901 | 67,412 | 1,610 | 36,360 | 566 | 1,100 | 43 |
| Electromagnetic | | | | | | | | |
| Frequency domain | | | 200 | 200 | | | | |
| Combined EM/Mag. | | | | | | | | |
| Time domain | 289 | 26 | 59,338 | 2,623 | | | | |
| Frequency domain | 1,250 | 135 | 40,000 | 2,950 | | | | |
| VLF | 12,000 | 500 | 31,826 | 1,184 | | | | |
| Radiometric | | | | | | | | |
| Gamma ray | | | 19,150 | 383 | | | | |
| Remote sensing | | | | | | | | |
| Multispectral scanning | 585 | 18 | | | | | | |
| Other | | | 11,363 | 331 | | | | |
| Total | 234,580 | 4,906 | 229,289 | 9,281 | 36,360 | 566 | 20,100 | 471 |

**Table 13B. Eastern Hemisphere airborne activity in US$ (thousands).**

| Survey method | Europe | | Africa | | Middle East | | Far East | | Australia/New Zealand | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Line-miles | Cost | Line-miles | Cost | Line-miles | Cost | Line-miles | Cost | Line-miles | Cost |
| Gravity | | | | | | | 2,500 | 164 | | |
| Magnetic | 43,313 | 1,056 | 14,463 | 480 | 15,224 | 354 | 90,700 | 3,845 | 254,298 | 2,214 |
| Combined EM/Mag. | | | | | | | | | | |
| Frequency domain | 6,300 | 790 | | | | | | | 5,000 | 500 |
| Radiometric | | | | | | | | | | |
| Gamma ray | 12,094 | 352 | 21,163 | 529 | | | | | | |
| Remote sensing | | | | | | | | | | |
| Multispectral scanning | 3,964 | 111 | 2,500 | 25 | | | 2,128 | 51 | 2,800 | 28 |
| Total | 65,671 | 2,310 | 38,126 | 1,034 | 15,224 | 354 | 95,328 | 4,060 | 262,098 | 2,742 |

**Table 14A. Western Hemisphere land mining activity in US$ (thousands).**

| Survey method | USA | | Canada | | Mexico | | South America | |
|---|---|---|---|---|---|---|---|---|
| | Line-miles [stations] | Cost | Line-miles [stations] | Cost | Line-miles [stations] | Cost | Line-miles [stations] | Cost |
| Seismic (*P*-wave) | | | | | | | | |
| Dynamite | 2 | 18 | | | | | | |
| Dynamite | [100,000] | 200 | | | | | | |
| Other | 3 | 1 | | | | | | |
| Seismic (*S*-wave) | | | | | | | | |
| Weight drop | 55 | 11 | | | | | | |
| Seismic (refraction) | | | | | | | | |
| Dynamite | | | 24 | 69 | 50 | 46 | | |
| Weight drop | 2 | 3 | | | | | | |
| Gravity | 672 | 34 | 60 | 50 | 62 | 23 | | |
| Gravity | [150] | 3 | [824] | 240 | | | | |
| Magnetic | 185 | 9 | 920 | 131 | 261 | 10 | | |
| Resistivity | | | | | 20 | 4 | | |
| Resistivity | [49] | 2 | | | | | | |
| Electromagnetic | | | | | | | | |
| Time domain | | | 310 | 132 | | | | |
| Frequency domain | 307 | 299 | 620 | 174 | | | | |
| VLF | | | 385 | 36 | | | | |
| Combined EM/Mag. | | | | | | | | |
| Time domain | 48 | 13 | | | | | | |
| Frequency domain | 102 | 19 | 306 | 116 | | | | |
| VLF | 20 | 10 | 722 | 297 | | | | |
| Induced polarization | | | | | | | | |
| Time domain | 211 | 272 | 762 | 788 | 350 | 50 | 14 | 8 |
| Frequency domain | | | 30 | 48 | 28 | 10 | | |
| Complex resistivity | 4 | 30 | | | | | | |
| Magnetotelluric | | | | | | | | |
| Natural field | [20] | 80 | | | | | | |
| Controlled source | 43 | 45 | | | | | | |
| Controlled source | [918] | 138 | | | | | | |
| Radiometric | | | | | | | | |
| Gamma ray | | | [1,000] | 24 | | | [950] | 12 |
| Other | 8 | 15 | | | | | | |
| Total | 1,662 [101,137] | 1,206 | 4,139 [1,824] | 2,113 | 771 | 144 | 14 [950] | 20 |

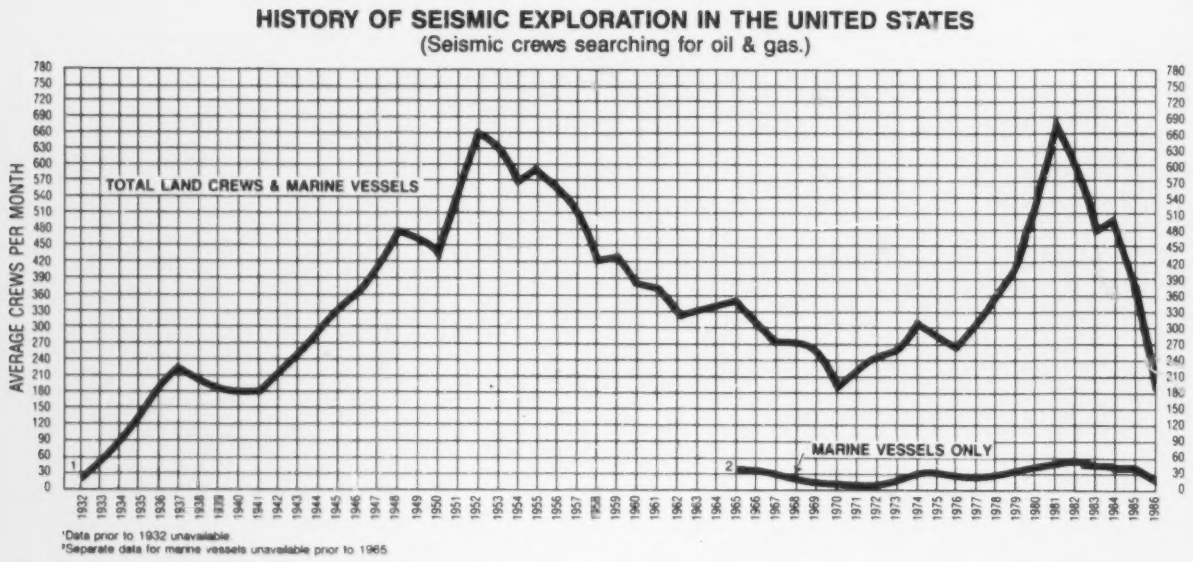


FIG. 5 History of seismic exploration activity in the U.S., 1932-1986. (The total crews working in a given year is not synonymous with the crew-months worked that year.)

**Table 14B. Eastern Hemisphere land mining activity in US$ (thousands).**

| | Europe | | Africa | | Far East | | Australia/New Zealand | |
|---|---|---|---|---|---|---|---|---|
| Survey method | Line-miles [stations] | Cost | Line-miles [stations] | Cost | Line-miles [stations] | Cost | Line-miles [stations] | Cost |
| Seismic (*P*-wave) | | | | | | | | |
| Dynamite | 432 | 4,338 | | | | | 70 | 216 |
| Weight drop | | | | | | | 550 | 620 |
| Vibratory | 61 | 198 | | | | | 150 | 370 |
| Seismic (refraction) | | | | | | | | |
| Dynamite | | | | | | | 20 | 50 |
| Weight drop | | | 50 | 150 | | | | |
| Gravity | | | 1,154 | 163 | | | 43 | 10 |
| Gravity | | | | | | | [700] | 46 |
| Magnetic | 25 | 3 | 1,508 | 93 | 12 | 21 | 803 | 78 |
| Resistivity | 625 | 150 | 121 | 102 | 10 | 5 | | |
| Electromagnetic | | | | | | | | |
| Time domain | | | 211 | 115 | 27 | 11 | 26 | 28 |
| Frequency domain | 55 | 31 | 135 | 33 | | | | |
| VLF | 70 | 7 | 17 | 5 | | | 15 | 2 |
| Combined EM/Mag. | | | | | | | | |
| Time domain | | | 639 | 55 | | | 1,250 | 500 |
| Time domain | | | | | | | [500] | 10 |
| Induced polarization | | | | | | | | |
| Time domain | | | 112 | 101 | | | 22 | 37 |
| Frequency domain | | | | | 43 | 12 | | |
| Magnetotelluric | | | | | | | | |
| Controlled source | | | | | 107 | 18 | 11 | 14 |
| Radiometric | | | | | | | | |
| Gamma ray | | | | | | | 12 | 5 |
| Other | [400] | 8 | 1 | 10 | | | | |
| Total | 1,268 [400] | 4,738 | 3,948 | 827 | 199 | 67 | 2,972 [1,200] | 1,990 |

**Table 15. Worldwide groundwater and engineering activity.**

| Survey method | Area | | | Time | | Cost |
|---|---|---|---|---|---|---|
| | Line-miles | Stations | Footage | Crew-months | Man-months | US$ (thousands) |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 232 | 10,000 | | 6.2 | 2.0 | 346.3 |
| Compressed air | 9,097 | | | 17.7 | | 2,440.0 |
| Electrical | 11,690 | | | 21.3 | | 2,617.2 |
| Gas exploder | 733 | | | 1.0 | | 865.0 |
| Implosive | 530 | | | 1.1 | | 440.0 |
| Weight drop | 41 | | | 5.0 | 1.0 | 217.5 |
| Vibratory | 44 | | | 1.8 | | 110.0 |
| Seismic (*S*-wave) | | | | | | |
| Other | 1 | | | 1.0 | | 2.5 |
| Seismic (refraction) | | | | | | |
| Dynamite | 314 | 2 | | 27.5 | 12.5 | 697.2 |
| Weight drop | 279 | | | 21.1 | 4.2 | 678.9 |
| Solid chemical | 6 | 10 | | 1.3 | 2.5 | 64.5 |
| Gravity | 40 | 14,272 | | 23.5 | 2.3 | 681.2 |
| Magnetic | 14,659 | 2,235 | | 7.0 | 1.3 | 369.8 |
| Resistivity | 1,203 | 408 | 412,297 | 67.9 | 42.0 | 943.5 |
| Self-potential | | 1,000 | 11,459 | .4 | 2.0 | 26.5 |
| Sonic/velocity logging | | | 4,700 | | 5.2 | 15.8 |
| Electromagnetic | | | | | | |
| Time domain | 101 | 40 | | 4.1 | 8.0 | 108.8 |
| Frequency domain | 1 | 1,000 | | 1.0 | | 4.2 |
| VLF | | 40 | | | .5 | 10.0 |
| Combined EM/Mag. | | | | | | |
| Time domain | | 28 | | | .9 | 1.7 |
| Frequency domain | 250 | | | .3 | | 40.0 |
| Induced polarization | | | | | | |
| Time domain | | 25 | | 1.0 | | .9 |
| Frequency domain | 156 | | | 4.0 | | 64.0 |
| Magnetotelluric | | | | | | |
| Natural field | | 10 | | 2.2 | | 120.0 |
| Controlled source | | 40 | | .2 | | 9.5 |
| Radiometric | | | | | | |
| Gamma ray | | | 17,073 | 1.5 | .1 | 21.0 |
| Alpha track | | | 2,500 | 1.5 | | 2.5 |
| Neutron activation | | | 2,500 | | .7 | 2.5 |
| Remote sensing | | | | | | |
| Other | 800 | | | 1.0 | | 200.0 |
| Temperature gradient | | 400 | 10,500 | 4.1 | .5 | 12.0 |
| VSPs | | | 1,210 | | | 2.5 |
| Other | 25,659 | 9,006 | 63,879 | 69.6 | 12.4 | 1,855.5 |
| Total | 65,839 | 38,516 | 526,118 | 294.8 | 98.4 | 12,971.6 |

**Table 16. Worldwide geothermal activity.**

| Survey method | Area | | Time | | Cost |
|---|---|---|---|---|---|
| | Line-miles | Stations | Crew-months | Man-months | US$ (thousands) |
| Gravity | 100 | 495 | 4.0 | | 118.9 |
| Magnetic | 700 | | 1.0 | | 45.0 |
| Resistivity | 138 | | 4.0 | | 35.0 |
| Electromagnetic | | | | | |
| Time domain | | 120 | 1.0 | | 600.0 |
| Frequency domain | 40 | | 2.0 | | 100.0 |
| Combined EM/Mag. | | | | | |
| Time domain | | 26 | | 1.7 | 75.0 |
| Magnetotelluric | | | | | |
| Natural field | | 50 | 2.0 | | 175.0 |
| Total | 978 | 691 | 14.0 | 1.7 | 1,148.9 |

**Table 17. Worldwide average unit costs by survey objective, type, and method.**

| Survey objective, type, and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs - US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew-month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Petroleum exploration** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 2,142.9 | 113,138 | 412,690,508 | 53 | 192,579 | 3,648 |
| Compressed air | 78.3 | 5,988 | 16,888,496 | 76 | 215,690 | 2,820 |
| Gas exploder | 38.6 | 1,864 | 9,497,789 | 48 | 246,057 | 5,095 |
| Weight drop | 58.3 | 4,208 | 19,777,215 | 72 | 339,232 | 4,699 |
| Solid chemical | .3 | 9 | 36,051 | 27 | 109,245 | 4,006 |
| Vibratory | 2,193.7 | 134,000 | 448,942,824 | 61 | 204,644 | 3,350 |
| Other | .5 | 13 | 88,000 | 26 | 176,000 | 6,769 |
| Seismic (*S*-wave) | | | | | | |
| Dynamite | 1.5 | 10 | 133,000 | 7 | 88,667 | 12,667 |
| Seismic (refraction) | | | | | | |
| Dynamite | .5 | 2 | 10,000 | 5 | 20,000 | 4,000 |
| 3-D seismic | | | | | | |
| Line miles | 11.5 | 10,278 | 3,842,392 | 894 | 334,121 | 374 |
| Square miles | 9.7 | 180 | 3,890,000 | 19 | 401,031 | 21,575 |
| VSPs | 44.5 | [143] | 1,892,076 | [3] | 42,519 | [13,231] |
| Gravity | 234.3 | 12,843 | 1,446,660 | 55 | 6,174 | 113 |
| Gravity | 51.3 | [47,060] | 1,529,278 | [917] | 29,810 | [32] |
| Gravity | 14.0* | [10,700] | 1,019,000 | [764]* | 72,786* | [95] |
| Magnetic | 4.0 | 110 | 4,600 | 28 | 1,150 | 42 |
| Magnetic | 3.5 | [7,134] | 335,298 | [2,038] | 95,799 | [47] |
| Magnetic | 1.0* | [300] | 10,000 | [300]* | 10,000* | [33] |
| Resistivity | 17.0 | 816 | 204,000 | 48 | 12,000 | 250 |
| Electromagnetic | | | | | | |
| Time domain | .5 | [55] | 82,000 | [110] | 164,000 | [1,491] |
| Frequency domain | 2.0 | 9 | 5,000 | 5 | 2,500 | 556 |
| Induced polarization | | | | | | |
| Time domain | 3.0 | 7 | 26,000 | 2 | 8,667 | 3,714 |
| Magnetotelluric | | | | | | |
| Natural field | 1.0 | 150 | 75,000 | 150 | 75,000 | 500 |
| Natural field | 18.7 | [255] | 290,404 | [14] | 15,530 | [1,139] |
| Remote sensing | | | | | | |
| Thermal infrared | 3.0 | (90,000) | 60,000 | (30,000) | 20,000 | (1) |
| Other | 23.8 | 988 | 7,147,340 | 42 | 300,308 | 7,234 |
| Other | 48.0 | [96] | 2,153,000 | [2] | 44,854 | [22,427] |
| Transition zone | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 13.1 | 419 | 3,827,786 | 32 | 292,197 | 9,136 |
| Compressed air | 19.9 | 1,698 | 1,811,800 | 85 | 91,045 | 1,067 |
| Gas exploder | 6.3 | 253 | 3,109,283 | 40 | 493,537 | 12,261 |
| Solid chemical | 2.2 | 142 | 1,100,000 | 63 | 488,889 | 7,714 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 711.9 | 635,019 | 287,334,767 | 892 | 403,594 | 452 |
| Implosive | 15.6 | 9,839 | 3,522,136 | 630 | 225,489 | 358 |
| Vibratory | 1.0 | 500 | 225,000 | 500 | 225,000 | 450 |
| 3-D Seismic | | | | | | |
| Line miles | 59.9 | 62,300 | 25,896,300 | 1,039 | 431,893 | 416 |
| VSPs | .2 | [1] | 100,000 | [5] | 500,000 | [100,000] |
| Gravity | 9.0 | 6,070 | 182,000 | 674 | 20,222 | 30 |
| Gravity | 79.0* | 58,540 | 1,947,000 | 741* | 24,646* | 33 |
| Gravity | 2.0* | [517] | 220,000 | [259]* | 110,000* | [426] |
| Other | 6.7 | 26,540 | 11,943,000 | 3,949 | 1,777,232 | 450 |

**Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).**

| Survey objective, type, and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Petroleum exploration,** continued | | | | | | |
| Airborne | | | | | | |
| Gravity | 2.5 | 21,500 | 592,000 | 8,600 | 236,800 | 28 |
| Magnetic | 50.8 | 278,301 | 5,541,712 | 5,473 | 108,982 | 20 |
| Magnetic | .1* | 600 | 7,200 | 20,000* | 240,000* | 12 |
| Combined EM/Mag. | | | | | | |
| VLF | .1 | 85 | 4,000 | 1,700 | 80,000 | 47 |
| Radiometric | | | | | | |
| Gamma ray | 5.8 | 31,257 | 781,425 | 5,361 | 134,035 | 25 |
| Remote sensing | | | | | | |
| Multispectral scanning | 1.2 | 2.376 | 59,008 | 1,901 | 47,206 | 25 |
| Drill hole | | | | | | |
| Sonic/velocity logging | 14.0 | (84,000) | 315,000 | (6,000) | 22,500 | (4) |
| Magnetotelluric | | | | | | |
| Natural field | 4.0 | (130,000) | 70,000 | (32,500) | 17,500 | (1) |
| Remote sensing | | | | | | |
| Thermal infrared | 3.0 | (30,000) | 60,000 | (10,000) | 20,000 | (2) |
| Other | 1.5 | [37,030] | 260,000 | [24,687] | 173,333 | [7] |
| Other | .4* | (20,800) | 174,000 | (52,000)* | 435,000* | (8) |
| **Petroleum development** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 26.7 | 454 | 1,230,000 | 17 | 46,067 | 2,709 |
| Vibratory | 4.9 | 88 | 270,100 | 18 | 55,122 | 3,069 |
| 3-D seismic | | | | | | |
| Line miles | 3.0 | 128 | 1,264,620 | 43 | 421,540 | 9,880 |
| Square miles | 1.5 | 14 | 150,000 | 10 | 100,000 | 10,345 |
| VSPs | 3.9 | [28] | 574,420 | [7] | 147,287 | [20,515] |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 5.5 | 2,218 | 2,337,800 | 403 | 425,055 | 1,054 |
| 3-D seismic | | | | | | |
| Line miles | 6.0 | 9,578 | 2,999,000 | 1,596 | 499,833 | 313 |
| Other | .2 | 60 | 20,000 | 240 | 80,000 | 333 |
| Drill hole | | | | | | |
| Sonic/velocity logging | 5.8 | [20,392] | 16,314 | [3,516] | 2.813 | [1] |
| **Minerals** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 27.5 | 505 | 4,572,122 | 18 | 166,259 | 9,054 |
| Weight drop | 18.0 | 550 | 620,000 | 31 | 34,444 | 1,127 |
| Vibratory | 6.3 | 211 | 568,000 | 33 | 90,159 | 2,692 |
| Other | 2.0 | 3 | 1,500 | 2 | 750 | 500 |
| Seismic (*S*-wave) | | | | | | |
| Weight drop | 1.0 | 55 | 11,000 | 55 | 11,000 | 200 |
| Seismic (refraction) | | | | | | |
| Dynamite | 10.0 | 94 | 165,950 | 9 | 16,595 | 1,749 |
| Weight drop | 3.5 | 52 | 153,200 | 15 | 43,771 | 2,946 |
| Gravity | 15.0 | 1,925 | 264,750 | 128 | 17,650 | 137 |
| Gravity | 3.4 | [1,224] | 280,000 | [360] | 82,353 | [229] |
| Gravity | 4.0* | 66 | 16,750 | 17* | 4,188* | 252 |
| Gravity | 2.1* | [450] | 9,700 | [214]* | 4,619* | [22] |
| Magnetic | 49.4 | 2,444 | 228,535 | 49 | 4,622 | 93 |
| Magnetic | 23.0* | 1,271 | 118,880 | 55* | 5,169* | 93 |

**Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).**

| Survey objective, type, and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Minerals**, Land, continued | | | | | | |
| Resistivity | 19.7 | 776 | 261,210 | 39 | 13,259 | 337 |
| Resistivity | .5 | [49] | 2,500 | [98] | 5,000 | [51] |
| Electromagnetic | | | | | | |
| Time domain | 21.7 | 527 | 243,730 | 24 | 11,206 | 462 |
| Time domain | 4.0* | 49 | 43,500 | 12* | 10,875* | 879 |
| Frequency domain | 27.2 | 947 | 498,600 | 35 | 18,297 | 527 |
| Frequency domain | 5.2* | 170 | 39,000 | 32* | 7,429* | 229 |
| VLF | 2.6 | 245 | 19,800 | 94 | 7,615 | 81 |
| VLF | 2.5* | 242 | 31,400 | 97* | 12,560* | 130 |
| Combined EM/Mag. | | | | | | |
| Time domain | 35.4 | 1,929 | 563,000 | 54 | 15,904 | 292 |
| Time domain | 7.0 | [500] | 10,710 | [71] | 1,530 | [21] |
| Time domain | 1.0* | 8 | 5,000 | 8* | 5,000* | 625 |
| Frequency domain | 8.0 | 306 | 116,000 | 38 | 14,500 | 379 |
| Frequency domain | 4.2* | 102 | 19,000 | 24* | 4,471* | 186 |
| Combined EM/Mag. | | | | | | |
| VLF | 20.3 | 742 | 307,200 | 37 | 15,133 | 414 |
| Induced polarization | | | | | | |
| Time domain | 75.9 | 1,410 | 1,203,832 | 19 | 15,861 | 853 |
| Time domain | 8.5* | 62 | 53,300 | 7* | 6,271* | 860 |
| Frequency domain | 6.0 | 101 | 70,000 | 17 | 11,667 | 693 |
| Complex resistivity | 2.0 | 4 | 30,000 | 2 | 15,000 | 7,500 |
| Magnetotelluric | | | | | | |
| Natural field | 4.7 | [20] | 80,000 | [4] | 16,842 | [4,000] |
| Controlled source | 5.0 | 118 | 32,000 | 24 | 6,400 | 270 |
| Controlled source | 3.0 | [918] | 138,370 | [306] | 46,123 | [151] |
| Controlled source | 9.0* | 43 | 45,000 | 5* | 5,000* | 1,047 |
| Radiometric | | | | | | |
| Gamma ray | 1.0 | 12 | 5,600 | 13 | 5,600 | 448 |
| Gamma ray | 3.0 | [950] | 12,000 | [317] | 4,000 | [13] |
| Gamma ray | .1* | 1 | 200 | 1* | 2,000* | 2,000 |
| Gamma ray | 6.0* | [1,000] | 24,000 | [167]* | 4,000* | [24] |
| Other | 2.0 | [400] | 8,000 | [200] | 4,000 | [20] |
| Other | 3.8* | 9 | 25,000 | 2* | 6,579* | 2,778 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Electrical | 1.0 | 120 | 30,000 | 120 | 30,000 | 250 |
| Other | .2 | 125 | 81,250 | 500 | 325,000 | 650 |
| Seismic (refraction) | | | | | | |
| Compressed air | .9 | 4,444 | 213,000 | 4,938 | 236,667 | 48 |
| Airborne | | | | | | |
| Magnetic | 50.8 | 280,370 | 6,578,740 | 5,510 | 129,299 | 23 |
| Magnetic | .1* | 500 | 63,000 | 10,000* | 1,260,000* | 126 |
| Combined EM/Mag. | | | | | | |
| Time domain | 15.8 | 59,627 | 2,649,000 | 3,774 | 167,658 | 44 |
| Frequency domain | 15.0 | 52,300 | 4,340,000 | 3,487 | 289,333 | 83 |
| VLF | 13.6 | 31,741 | 1,180,780 | 2,334 | 86,822 | 37 |
| Radiometric | | | | | | |
| Gamma ray | 1.8 | 7,000 | 140,000 | 3,889 | 77,778 | 20 |
| Remote sensing | | | | | | |
| Multispectral scanning | .5 | 337 | 10,784 | 674 | 21,568 | 32 |
| Multispectral scanning | 2.0* | 5,300 | 53,000 | 2,650* | 26,500* | 10 |
| Other | 2.2 | 11,363 | 331,000 | 5,165 | 150,455 | 29 |

**Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).**

| Survey objective, type, and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Minerals,** continued | | | | | | |
| Drill hole | | | | | | |
| Resistivity | .3 | (3,445) | 5,000 | (11,483) | 16,667 | (1) |
| Resistivity | 2.0* | (1,120) | 11,000 | (546)* | 5,366* | (10) |
| Sonic/velocity logging | .6* | (6,100) | 3,200 | (10,167)* | 5,333* | (1) |
| Electromagnetic | | | | | | |
| Time domain | 1.0 | (5,000) | 10,000 | (5,000) | 10,000 | (2) |
| VLF | .1* | (2,100) | 1,000 | (21,000)* | 10,000* | (1) |
| Induced polarization | | | | | | |
| Time domain | 2.0* | (1,000) | 10,000 | (500)* | 5,000* | (10) |
| Radiometric | | | | | | |
| Gamma ray | 4.0 | (115,000) | 21,000 | (28,750) | 5,250 | (1) |
| Gamma ray | 2.0* | (3,000) | 3,000 | (1,500)* | 1,500* | (1) |
| Other | 7.0 | [108,000] | 227,000 | [15,429] | 32,429 | [2] |
| Other | .3* | (2,395) | 2,800 | (7,983)* | 9,333* | (1) |
| **Environmental** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | .5 | 1 | 10,000 | 2 | 20,000 | 10,000 |
| Seismic (refraction) | | | | | | |
| Dynamite | 3.0 | 7 | 40,000 | 2 | 13,333 | 5,556 |
| Weight drop | 1.1* | 1 | 5,000 | 1* | 4,274* | 3,333 |
| Gravity | 1.0* | [800] | 3,750 | [800]* | 3,750* | [5] |
| Magnetic | 6.3 | 687 | 104,000 | 108 | 16,378 | 151 |
| Magnetic | .1* | [100] | 800 | [1,000]* | 8,000* | [8] |
| Resistivity | 1.7 | 46 | 28,000 | 27 | 16,471 | 609 |
| Resistivity | 5.7 | [899] | 65,331 | [158] | 11,462 | [73] |
| Self-potential | .3 | [500] | 20,632 | [1,667] | 68,773 | [41] |
| Electromagnetic | | | | | | |
| Time domain | 1.1 | 32 | 53,000 | 29 | 48,182 | 1,656 |
| Time domain | .5* | 1 | 650 | 2* | 1,300* | 650 |
| Time domain | .5* | [20] | 10,000 | [40]* | 20,000* | [500] |
| Frequency domain | 7.0 | 330 | 160,000 | 47 | 22,857 | 485 |
| Frequency domain | .3* | 31 | 5,000 | 104* | 16,667* | 160 |
| Combined EM/Mag. | | | | | | |
| Frequency domain | .1 | 1 | 250 | 2 | 5,000 | 2,500 |
| VLF | .2 | [100] | 10,000 | [500] | 50,000 | [100] |
| Induced polarization | | | | | | |
| Time domain | .5 | 2 | 1,000 | 6 | 2,000 | 357 |
| Time domain | .2 | [12] | 450 | [48] | 1,800 | [38] |
| Radiometric | | | | | | |
| Gamma ray | 360.0* | [1,200] | 1,500,000 | [3]* | 4,167* | [1,250] |
| Remote sensing | | | | | | |
| Other | .5 | 6 | 12,000 | 12 | 24,000 | 2,000 |
| Other | 1.0* | 8 | 35,000 | 8* | 35,000* | 4,375 |
| Other | .8* | [130] | 14,000 | [163]* | 17,500* | [108] |
| Marine | | | | | | |
| Other | 2.4 | 6,700 | 615,000 | 2,757 | 253,086 | 92 |
| Airborne | | | | | | |
| Remote sensing | | | | | | |
| Multispectral scanning | .5 | 1,942 | 46,608 | 3,884 | 93,216 | 24 |
| Drill hole | | | | | | |
| Other | .8 | (2,500) | 15,000 | (3,125) | 18,750 | (6) |

**Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).**

| Survey objective, type, and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Engineering** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 2.0 | 55 | 275,000 | 28 | 137,500 | 5,000 |
| Dynamite | 4.0 | [10,000] | 20,000 | [2,500] | 5,000 | [2] |
| Dynamite | 2.0* | 2 | 1,300 | 1* | 650* | 520 |
| Weight drop | 2.0 | 25 | 200,000 | 13 | 100,000 | 8,000 |
| Vibratory | 1.8 | 44 | 110,000 | 24 | 61,111 | 2,500 |
| Seismic (refraction) | | | | | | |
| Dynamite | 15.5 | 236 | 647,140 | 15 | 41,617 | 2,742 |
| Dynamite | 1.0 | [2] | 16,000 | [2] | 16,000 | [8,000] |
| Dynamite | 12.5* | 15 | 29,065 | 1* | 2,325* | 1,925 |
| Weight drop | 11.1 | 91 | 231,470 | 8 | 20,685 | 2,532 |
| Weight drop | 2.5* | 15 | 50,000 | 6* | 20,000* | 3,226 |
| Solid chemical | 1.3 | 3 | 24,532 | 2 | 18,871 | 8,177 |
| Solid chemical | 2.0* | 3 | 25,000 | 2* | 12,500* | 7,143 |
| Solid chemical | .5* | [10] | 15,000 | [20]* | 30,000* | [1,500] |
| Gravity | 11.0 | [4,290] | 209,880 | [390] | 19,080 | [49] |
| Magnetic | .3 | 50 | 7,000 | 167 | 23,333 | 140 |
| Magnetic | 1.0 | [2,000] | 3,000 | [2,000] | 3,000 | [2] |
| Magnetic | .2* | [200] | 1,000 | [800]* | 4,000* | [5] |
| Resistivity | 3.7 | 84 | 40,000 | 22 | 10,667 | 476 |
| Resistivity | .2 | [27] | 9,500 | [135] | 47,500 | [352] |
| Resistivity | 6.0* | 17 | 28,500 | 3* | 4,750* | 1,676 |
| Resistivity | 25.5* | [215] | 255,000 | [8]* | 10,000* | [1,186] |
| Self-potential | .5* | [1,000] | 10,000 | [2,000]* | 20,000* | [10] |
| Electromagnetic | | | | | | |
| Time domain | 2.0 | 37 | 50,500 | 19 | 25,250 | 1,350 |
| Frequency domain | 1.0 | [1,000] | 4,000 | [1,000] | 4,000 | [4] |
| VLF | .5* | [40] | 10,000 | [8]* | 20,000* | [250] |
| Combined EM/Mag. | | | | | | |
| Frequency domain | .2 | 1 | 5,000 | 1 | 20,000 | 25,000 |
| Other | 12.9 | 25,085 | 1,031,300 | 1,945 | 79,946 | 41 |
| Other | 3.0 | [200] | 30,000 | [67] | 10,000 | [150] |
| Other | .5* | 9 | 17,000 | 9* | 17,895* | 1,889 |
| Other | 2.0* | [6] | 81,000 | [3]* | 40,500* | [13,500] |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | .2 | 175 | 50,000 | 700 | 200,000 | 286 |
| Compressed air | 17.7 | 9,097 | 2,440,000 | 513 | 137,465 | 268 |
| Electrical | 21.3 | 11,690 | 2,617,250 | 549 | 122,876 | 224 |
| Gas exploder | 1.0 | 733 | 865,000 | 733 | 865,000 | 1,180 |
| Implosive | 1.1 | 530 | 440,000 | 482 | 400,000 | 830 |
| Remote sensing | | | | | | |
| Other | 1.0 | 800 | 200,000 | 800 | 200,000 | 250 |
| Other | 1.7 | 535 | 218,000 | 315 | 128,235 | 407 |
| Airborne | | | | | | |
| Magnetic | .7 | 1,900 | 54,000 | 2,533 | 72,000 | 28 |
| Drill hole | | | | | | |
| Self-potential | 1.5* | (5,700) | 10,750 | (3,800)* | 7,167* | (2) |
| Sonic/velocity logging | 4.5* | (3,700) | 12,000 | (822)* | 2,667* | (3) |
| Temperature gradient | 4.1 | [400] | 2,000 | [98] | 488 | [5] |
| Other | 44.0 | [8,800] | 175,000 | [200] | 3,977 | [20] |
| Other | 3.7 | (19,100) | 115,000 | (5,162) | 31,081 | (6) |
| Other | 7.5* | (11,779) | 80,000 | (1,571)* | 10,667* | (7) |

**Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).**

| Survey objective, type, and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Geothermal** | | | | | | |
| Land | | | | | | |
| Gravity | 2.0 | 100 | 100,000 | 50 | 50,000 | 1,000 |
| Gravity | 2.0 | [495] | 18,900 | [248] | 9,450 | [38] |
| Resistivity | 4.0 | 138 | 35,000 | 35 | 8,750 | 254 |
| Electromagnetic | | | | | | |
| Time domain | 1.0 | [120] | 600,000 | [120] | 600,000 | [5,000] |
| Frequency domain | 2.0 | 40 | 100,000 | 20 | 50,000 | 2,500 |
| Combined EM/Mag. | | | | | | |
| Time domain | 1.7* | [26] | 75,000 | [15]* | 44,118* | [2,885] |
| Magnetotelluric | | | | | | |
| Natural field | 2.0 | [50] | 175,000 | [25] | 87,500 | [3,500] |
| Airborne | | | | | | |
| Magnetic | 1.0 | 700 | 45,000 | 700 | 45,000 | 64 |
| **Groundwater** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Weight drop | 3.0 | 15 | 15,000 | 5 | 5,000 | 1,000 |
| Weight drop | 1.0* | 1 | 2,500 | 1* | 2,427* | 1,923 |
| Seismic (*S*-wave) | | | | | | |
| Other | 1.0 | 1 | 2,500 | 1 | 2,500 | 2,500 |
| Seismic (refraction) | | | | | | |
| Dynamite | 11.0 | 63 | 4,000 | 6 | 364 | 63 |
| Dynamite | .1* | 1 | 1,000 | 5* | 50,000* | 10,000 |
| Seismic (refraction) | | | | | | |
| Weight drop | 10.0 | 170 | 390,000 | 17 | 39,000 | 2,294 |
| Weight drop | 1.7* | 2 | 7,500 | 1* | 4,190* | 3,261 |
| VSPs | .1* | (1,210) | 2,500 | (121,000)* | 250,000* | (2) |
| Gravity | 12.5 | [9,936] | 465,712 | [795] | 37,257 | [47] |
| Gravity | 2.0* | 40 | 4,550 | 20* | 2,275* | 114 |
| Gravity | .3* | [46] | 1,150 | [153]* | 3,833* | [25] |
| Magnetic | 2.0 | 75 | 400 | 38 | 200 | 5 |
| Magnetic | 1.0* | 10 | 350 | 10* | 350* | 35 |
| Magnetic | .1* | [35] | 1,100 | [350]* | 11,000* | [31] |
| Resistivity | 42.0 | 1,102 | 358,285 | 26 | 8,531 | 325 |
| Resistivity | 2.0 | [95] | 12,970 | [48] | 6,485 | [137] |
| Resistivity | 5.0* | [71] | 10,000 | [14]* | 2,000* | [141] |
| Electromagnetic | | | | | | |
| Time domain | .6 | 25 | 5,300 | 43 | 8,833 | 208 |
| Time domain | 1.5 | [40] | 30,000 | [27] | 20,000 | [750] |
| Time domain | 8.0* | 39 | 23,065 | 5* | 2,883* | 591 |
| Frequency domain | .1 | 1 | 250 | 20 | 5,000 | 250 |
| Combined EM/Mag. | | | | | | |
| Time domain | .9* | [28] | 1,750 | [31]* | 1,944* | [63] |
| Induced polarization | | | | | | |
| Time domain | 1.0 | [25] | 900 | [25] | 900 | [36] |
| Frequency domain | 4.0 | 156 | 64,000 | 39 | 16,000 | 410 |
| Magnetotelluric | | | | | | |
| Natural field | 2.2 | [10] | 120,000 | [4] | 53,333 | [12,000] |
| Controlled source | .2 | [40] | 9,500 | [200] | 47,500 | [238] |
| Other | 2.0* | 30 | 52,000 | 15* | 26,000* | 1,733 |
| Airborne | | | | | | |
| Magnetic | 3.0 | 12,624 | 302,976 | 4,208 | 100,992 | 24 |

**Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).**

| Survey objective, type and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Groundwater**, Airborne, continued | | | | | | |
| Combined EM/Mag. | | | | | | |
| Frequency domain | .1 | 250 | 35,000 | 2,500 | 350,000 | 140 |
| Drill hole | | | | | | |
| Resistivity | 20.0 | (144,427) | 144,526 | (7,221) | 7,226 | (1) |
| Resistivity | 5.5* | (267,870) | 84,800 | (48,178)* | 15,252* | (1) |
| Self-potential | .4 | (5,759) | 5,750 | (14,398) | 14,375 | (1) |
| Sonic/velocity logging | .7* | (1,000) | 3,800 | (1,429)* | 5,429* | (4) |
| Radiometric | | | | | | |
| Gamma ray | 1.5 | (15,973) | 19,431 | (10,649) | 12,954 | (1) |
| Gamma ray | .1* | (1,100) | 1,650 | (11,000)* | 16,500* | (2) |
| Alpha track | 1.5 | (2,500) | 2,500 | (1,667) | 1,667 | (1) |
| Neutron activation | .7 | (2,500) | 2,500 | (3,571)* | 3,571* | (1) |
| Temperature gradient | .5* | (10,500) | 10,000 | (21,000)* | 20,000* | (1) |
| Other | 4.3 | (33,000) | 56,200 | (7,674) | 13,070 | (2) |
| **Oceanography** | | | | | | |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Electrical | .8 | 700 | 150,000 | 875 | 187,500 | 214 |
| Electrical | 5.0* | 8,922 | 720,000 | 1,784* | 144,000* | 81 |
| Implosive | 4.7 | 3,075 | 1,275,000 | 654 | 271,277 | 415 |
| Other | .8 | 526 | 325,650 | 658 | 407,063 | 619 |
| Other | 3.0 | 9,398 | 796,000 | 3,091 | 261,842 | 85 |
| Airborne | | | | | | |
| Magnetic | .5* | 17,856 | 303,552 | 35,712* | 607,104* | 17 |
| **Research** | | | | | | |
| Land | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Dynamite | 10.5 | 363 | 739,500 | 35 | 70,429 | 2,037 |
| Compressed air | 5.5 | 20 | 139,000 | 4 | 25,273 | 6,950 |
| Compressed air | 1.0* | 5 | 5,000 | 5* | 5,000* | 1,000 |
| Weight drop | 3.0 | 6 | 100,000 | 2 | 33,333 | 16,667 |
| Weight drop | 4.5* | [138] | 4,000 | [31]* | 889* | [29] |
| Vibratory | 12.2 | 582 | 2,492,535 | 48 | 204,306 | 4,283 |
| Seismic (refraction) | | | | | | |
| Dynamite | 5.0 | 955 | 1,850,000 | 191 | 370,000 | 1,937 |
| Dynamite | 4.0* | 25 | 16,000 | 6* | 4,000* | 640 |
| Weight drop | 1.0 | 3 | 3,000 | 3 | 3,000 | 1,000 |
| Weight drop | .6* | 1 | 2,600 | 1* | 4,000* | 2,889 |
| 3-D seismic | | | | | | |
| Line-miles | .5 | 52 | 63,778 | 104 | 127,556 | 1,227 |
| Gravity | 9.5 | 1,564 | 182,000 | 165 | 19,158 | 116 |
| Gravity | 6.2 | [2,505] | 25,500 | [404] | 4,113 | [10] |
| Gravity | 3.5* | 20 | 10,000 | 6* | 2,857* | 500 |
| Gravity | 26.1* | [9,320] | 100,364 | [357]* | 3,845* | [11] |
| Magnetic | 1.0 | 200 | 8,400 | 200 | 8,400 | 42 |
| Magnetic | 10.0 | [11,000] | 50,000 | [1,100] | 5,000 | [5] |
| Magnetic | .2* | 15 | 750 | 75* | 3,750* | 50 |
| Magnetic | 2.0* | [11,125] | 7,050 | [5,563]* | 3,525* | [1] |
| Resistivity | 2.7 | 470 | 39,500 | 171 | 14,364 | 84 |
| Resistivity | .2* | [150] | 200 | [750]* | 1,000* | [1] |
| Self-potential | 2.0* | 4 | 15,000 | 2* | 7,500* | 3,750 |

**Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).**

| Survey objective, type, and method | Total crew-months or man-months* | Miles or (footage) or [stations] | Acquisition costs – US$ | Average miles or (footage) or [stations]/ crew-month or man-month* | Average cost/ crew month or man-month* | Average cost/mile or (foot) or [station] |
|---|---|---|---|---|---|---|
| **Research,** Land, continued | | | | | | |
| Electromagnetic | | | | | | |
| Time domain | .7 | 37 | 10,000 | 50 | 13,333 | 267 |
| Time domain | .5 | [30] | 45,000 | [60] | 90,000 | [1,500] |
| Time domain | 2.0* | [30] | 5,000 | [15]* | 2,500* | [167] |
| Frequency domain | 1.0 | 3 | 2,500 | 3 | 2,500 | 833 |
| Frequency domain | 12.0* | 50 | 25,000 | 4* | 2,083* | 500 |
| Combined EM/Mag. | | | | | | |
| Time domain | .2* | [40] | 357 | [200]* | 1,785* | [9] |
| Magnetotelluric | | | | | | |
| Natural field | 2.0 | 150 | 100,000 | 75 | 50,000 | 667 |
| Natural field | 5.0 | [115] | 234,000 | [23] | 46,800 | [2,035] |
| Natural field | 7.0* | [60] | 51,000 | [9]* | 7,286* | [850] |
| Other | 20.0 | 5,000 | 150,000 | 250 | 7,500 | 30 |
| Other | 2.0* | 30 | 52,000 | 15* | 26,000* | 1,733 |
| Marine | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Compressed air | 3.3 | 9,757 | 1,308,407 | 2,930 | 392,915 | 134 |
| Passive monitoring | .1 | 598 | 65,000 | 4,600 | 500,000 | 109 |
| Gravity | .6 | 3,682 | 131,612 | 5,496 | 196,436 | 36 |
| Magnetic | 3.7 | 26,704 | 1,247,089 | 7,217 | 337,051 | 47 |
| Other | 6.8 | 34,899 | 1,737,700 | 5,080 | 252,940 | 50 |
| Airborne | | | | | | |
| Gravity | 3.0 | 2,400 | 325,000 | 800 | 108,333 | 135 |
| Magnetic | 8.7 | 139,000 | 925,000 | 15,886 | 105,714 | 7 |
| Magnetic | 2.1* | 9,075 | 252,000 | 4,221* | 117,209* | 28 |
| Electromagnetic | | | | | | |
| Frequency domain | 1.0 | 200 | 200,000 | 200 | 200,000 | 1,000 |
| Combined EM/Mag. | | | | | | |
| VLF | .7 | 12,000 | 500,000 | 16,000 | 666,667 | 42 |
| Radiometric | | | | | | |
| Gamma ray | 4.0 | 14,150 | 343,000 | 3,538 | 85,750 | 24 |
| Remote sensing | | | | | | |
| Multispectral scanning | 3.0 | 2,022 | 64,704 | 674 | 21,568 | 32 |
| Drill hole | | | | | | |
| Seismic (*P*-wave) | | | | | | |
| Vibratory | 1.0 | (14,000) | 50,000 | (14,000) | 50,000 | (4) |
| Seismic (*S*-wave) | | | | | | |
| Vibratory | 2.0 | (28,000) | 120,000 | (14,000) | 60,000 | (4) |
| Resistivity | .7* | (8,776) | 3,050 | (12,361)* | 4,296* | (1) |
| Self-potential | .8* | (15,431) | 4,750 | (19,289)* | 5,938* | (1) |
| Radiometric | | | | | | |
| Gamma ray | 1.2* | (22,446) | 10,000 | (18,705)* | 8,333* | (1) |
| Other | 6.9* | (15,400) | 37,000 | (2,232)* | 5,362* | (2) |

*(Continued from p. 36)*

antedates exploratory drilling by as much as 24 months, an increase in the number of wildcat wells in Nebraska, New Mexico, Michigan, and Washington can be anticipated for 1988-89.

Most of the marine seismic activity in U.S. waters was recorded along the Gulf Coast and the West Coast. All the transition zone data reported was for the Gulf Coast only. Tables 9 and 10 show petroleum seismic activity in Canada and Mexico, respectively.

A 54-year history of seismic exploration in the U.S. is shown in Figure 5.

## Gravity and magnetic surveys

Table 11 shows worldwide expenditures for gravity and magnetic surveys. The 1986 data show a large 51 percent decrease in expenditures in these methods as compared to 1985. Expenditures on gravity and magnetic surveys for petroleum exploration were down 65 percent as compared to an increase of 59 percent for mineral exploration.

## Airborne surveys

Statistical data on airborne surveys are shown in Tables 12, 13A, and 13B. Expenditures for worldwide airborne surveys decreased by 40 percent from 1985. The major decrease was in petroleum exploration which was down 76 percent in 1986 compared to 1985. Reporting for airborne activity in Canada was incomplete and the total expenditures reported may be in error by 50 percent.

## Land mining

Tables 14A and 14B report expenditures and methods utilized for land mining in the Western and Eastern Hemispheres.

## Engineering, geothermal, groundwater, oceanography, and research

Table 15 reports engineering and groundwater activity. Table 16 contains worldwide geothermal work. Average unit costs for all survey objectives, types, and methods can be found in Table 17. Expenditures for groundwater and engineering activity are up by 52 percent (Table 15). Geothermal activity is down from the previous year with a decrease in expenditures of 10 percent. Oceanography expenditures decreased by 61 percent and research decreased by 49 percent when compared to 1985 numbers.

## Summary

Expenditures continued to show a major decline in 1986 for use of geophysics in the petroleum area worldwide. Areas affected the most were the United States, Canada, and South America. These countries all showed an approximate 50 percent decrease in expenditures between 1985 and 1986. Activity in mining, engineering, and groundwater increased.

It is felt by the committee that this is probably the best reported year in several years. This is true for two reasons: first, there are fewer companies to contact and second, a more diligent effort was made this year to contact all the companies. In the future, 1986 may be considered the base standard for all future comparisons. One of the reasons that decreases were not greater may be that 1985 report numbers were low because of incomplete reporting.

## Acknowledgments

This report was made possible through the contributions of statistical data by companies, contractors, governmental agencies, and universities. For many of these organizations, compilation of these data was a long and tedious task. The Geophysical Activity Committee expresses sincere appreciation to all those individuals who were instrumental in preparing and submitting their activity questionnaires. The committee welcomes comments and suggestions on ways to improve this report.

L. G. (Whitey) Morris was responsible for much of the work in obtaining and maintaining the accuracy of these data for the Geophysical Activity Report. He is a retired geophysicist who volunteered his time for this project. We want to thank Whitey for all his contributions to this report. A special note of thanks goes to Jerry Henry, Sue Schulze, and the rest of the SEG staff who worked on this project. I would also like to thank H. T. Konkler for the long hours he worked with the computers and Russ Senti who again made a major contribution in the analysis and review of the data and this report. Russ was responsible for writing the section on geophysical activity under the topic of seismic surveys in the U.S. Every member of the Geophysical Activity Committee should be congratulated for help and advice in determining the direction of the work, updating address lists, and analyzing computer printouts for correctness.

## References

Geophysical Activity in 1985: LEADING EDGE, August 1986, 25-48.

*Published by*
*Society of Exploration Geophysicists*
*P.O. Box 702740*
*Tulsa, Oklahoma 74170-2740*
*U.S.A.*

Printed in USA